Space Weather Prediction at BBSO

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LONG-TERM GOALS

Our long term goal is to understand the physics and relationship among flares, filament eruptions, Coronal Mass Ejections (CMEs) and interplanetary magnetic clouds and to understand their surface magnetic origin, to understand their impact on the magnetosphere and ionosphere of the earth, and to predict them accurately.

OBJECTIVES

We concentrate on the study of magnetic origin of filament eruptions, flares and Coronal Mass Ejections (CMEs), which are vitally important in predicting and understanding the space weather, particularly, the solar origins of geomagnetic disturbances. We have the following objectives: Sustained sub-arc second resolution studies of active regions; high-cadence and high-resolution studies of solar flare emissions; and comprehensive studies of vector magnetic fields associated with flares, filament eruptions and CMEs.

APPROACH

Our research is mainly based on the analyses of data from two instruments developed at BBSO. (1) Global Halpha Network (GHN). The availability of full-disk, high-resolution Halpha images from Big Bear Solar Observatory (USA), Kanzelhohe Solar Observatory (Austria), Yunnan Astronomical Observatory (China), Huairou Solar Observing Station (China) and Catania Astrophysical Observatory (Italy) allows the continual monitoring of solar activity with unprecedented spatial and temporal resolution. Typically, our Global Halpha Network provides almost uninterrupted Halpha images with a cadence of 1-min and an image scale of 1” per pixel. This therefore facilitates automatic detection of flares, filament eruptions, and other energetic phenomena on a near real-time basis. (2) Digital Vector Magnetograph System which observes photospheric magnetic fields with high sensitivity and resolution.

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14. ABSTRACT
Our long term goal is to understand the physics and relationship among flares, filament eruptions, Coronal Mass Ejections (CMEs) and interplanetary magnetic clouds and to understand their surface magnetic origin, to understand their impact on the magnetosphere and ionosphere of the earth, and to predict them accurately.

15. SUBJECT TERMS

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WORK COMPLETED

We have developed and maintained the Active Region Monitor (ARM) system, a web-based solar activity monitoring tool which provides the most recent images from a variety of ground- and space-based solar observatories and can be found at www.bbso.njit.edu/arm. The software runs automatically every hour/the calculation of magnetic gradient is added to the ARM. In addition to providing images from the photosphere, chromosphere, and corona, the ARM pages include tables of active region data from NOAA, including up-to-date active region positions. Furthermore, a developmental version of the Flare Prediction System (FPS) has been included, which provides a table of region names together with flaring probabilities. Similarly to forecasters at NOAA's Space Environment Center, we have developed a flare prediction system based on the McIntosh active region classification scheme. Our system uses almost eight years of SEC flare occurrence and active region McIntosh classification data from November 1988 to June 1996, thus sampling the majority of activity in cycle 22. Probabilities are calculated based on tables of daily average flare rates.

We have also made significant progress in the relationship among flares, filament eruption, surface magnetic fields and interplanetary magnetic clouds.

RESULTS

1. Magnetic Field Evolution and Flares

BBSO's Digital Vector MagnetoGraph (DVMG) system has shown its power in studies of the evolution of magnetic fields at high resolution and cadence. One significant paper, Spirock et al. (2002, BBSO 1120), demonstrated a rapid/permanent increase of the limb-ward magnetic flux after a flare. This was explained by the emergence of very inclined magnetic flux.

To follow up this work, Wang et al. (2002a, BBSO 1125) presented results of studies of six X-class flares, all of which showed rapid and permanent changes in line-of-sight magnetic fields immediately after the flares. All the events showed an increase in the leading polarity magnetic flux of a few times 10^{20} Mx, and three of them showed some degree of decrease in the following polarity flux. The increases are quick (with a timescale for the overall change in the flux ranging from 10 to 110 min) and permanent. However, no satisfactory explanation has been found for this curious and provocative phenomenon. Wang et al. (2002b, BBSO 1158) also demonstrated a rapid disappearance of a small sunspot, which can be explained by fast magnetic reconnection or an emerging magnetic bubble.

Abramenko et al. (2003, BBSO 1182), studied the evolution of the magnetic structure of four events observed from BBSO, and convincingly demonstrated the avalanche theory of flares.

Figure 1 shows sample results of July 26, 2002 event. Top-left panel: line-of-sight magnetogram; Top-right panel: Halpha flare ribbons and RHESSI hard X-ray image after the peak of the flare; Bottom Panels: comparison of transverse magnetic field before and after the flare. Circles are areas of enhancement of longitudinal and transverse magnetic fields. It is obvious that transverse field increased after the flare, in the same place as the flare core.

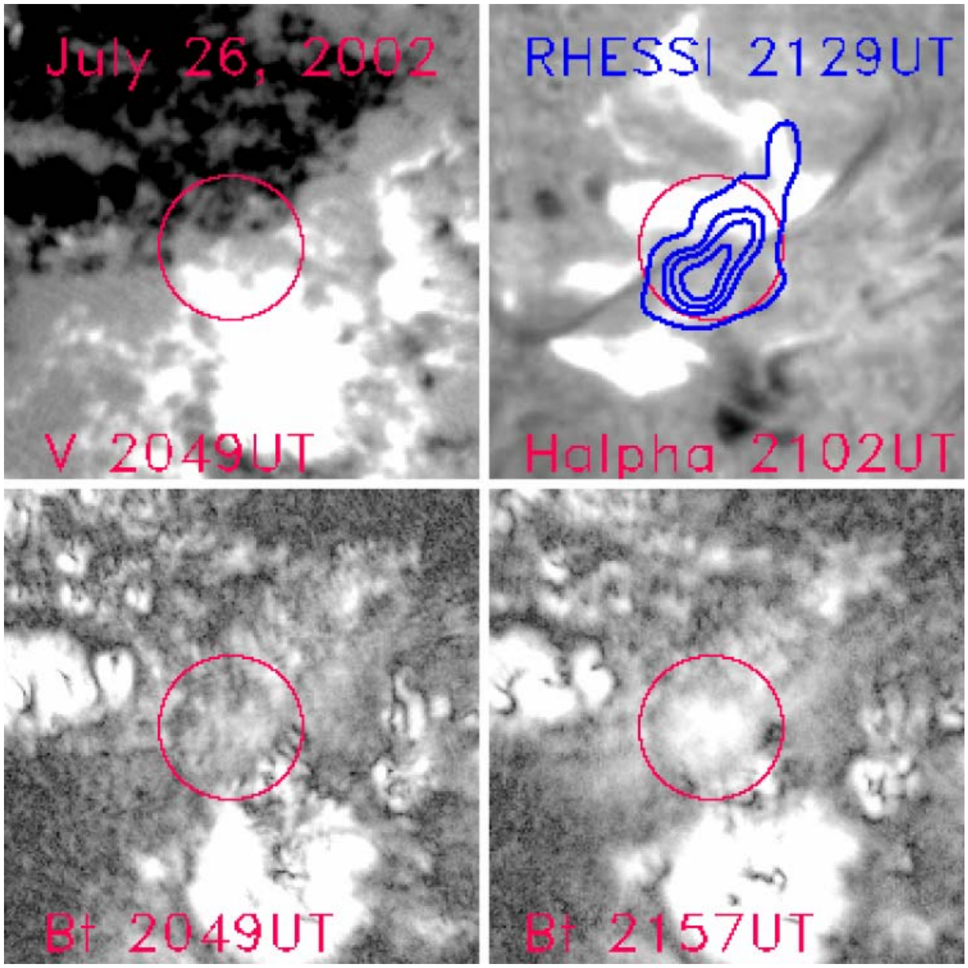

Figure 1

2. Study of Coronal Mass Ejections

We have been contributing to the understanding of the large-scale structure of Coronal Mass Ejections (CMEs). Wang et al. (2001, BBSO 1101) found the first direct evidence of sympathetic flares that directly connect different active regions. More recently, Wang et al. (2002, BBSO 1117) found an important correlation between magnetic "channels" and the onset of CMEs—an erupting magnetic flux rope in the channel. A magnetic channel is defined by alternating, elongated striations of positive and negative magnetic flux on small scales (a few arcsecs). Flows are observed along the field lines of the channel (Zirin and Wang, 1993). Our recent conclusions are that coronal dimming is due to chromospheric evaporation (BBSO 1117).

3. Space Weather Forecasting

We are continuing to carry out a statistical study of filament eruptions and flares, their underlying magnetic structure, the onset of CMEs, interplanetary magnetic clouds and geomagnetic storms. The results from our statistical study provide better tools for predicting abrupt changes in solar activity, and the often consequent geomagnetic storms. Filament eruptions and flares are compared with magnetic fields observed by ACE.

Every hour, images from our Global Halpha Network (GHN) are transferred to the web-based BBSO Active Region Monitor (ARM, www.bbso.njit.edu/arm), which also includes the most recent full-disk EUV, soft X-ray, continuum and magnetogram data from the Solar and Heliospheric Observatory (SoHO). ARM also includes a variety of active region properties from the National Oceanic and Atmospheric Administration's (NOAA) Space Environment Center (SEC), such as up-to-date active region positions and flare identifications. ARM was developed over the last two years (Gallagher et al., 2002, BBSO 1136).

Furthermore, we have developed a Flare Prediction System (FPS) that estimates the probability for each active region to produce C-, M-, or X-class flares based on nearly eight years of NOAA data from cycle 22. This, in addition to BBSO's daily solar activity reports, has been proven to be a useful resource for activity forecasting (BBSO 1104).

Yurchyshyn et al. (2003, BBSO 1168) proposed a novel method to predict geo-effective CMEs and the arrival of geomagnetic storms. So far, the success rate is 100% based on the study of about 20 events.

IMPACT/APPLICATIONS

The prediction of solar activity is so important in many areas since magnetic eruptions can have deleterious effects on satellites, upper atmosphere communications and even the North American power grid. Thus, it is critical to have the most reliable early warning system possible. For the Navy, the important factor appears to be their effects on VLF communication and on satellites, such as those involved in communication, surveillance and the global positioning system.

TRANSITIONS

Our data on World Wide Web has been used wide in the world to monitor solar activity. Our BBSO activity report and warnings, active region monitoring and flare prediction system have been highly regarded in the community.

RELATED PROJECTS

NSF Grant—Operation of Global Halpha Network, which provides data for the current study.

PUBLICATIONS

BBSO 1120: Rapid Changes in the Longitudinal Magnetic Field Related with the 2001 April 2 X20 Flare, T. J. Spirock, V.B., Yurchyshyn & H. Wang, 2002, ApJ, 572, 1072, [published, refereed]

BBSO 1125: Rapid Changes of Magnetic Fields Associated with Six X-Class Flares, H. Wang, T. J. Spirock, J. Qiu, H. Ji, V. Yurchyshyn, Y. J. Moon, C. Denker & P. R. Goode, 2002, ApJ, 576, 497, [published, refereed]

BBSO 1127: Flare Activity and Magnetic Helicity Injection by Photospheric Horizontal Motions, Y.-J. Moon, J. Chae, G. S. Choe, H. Wang, Y.D. Park, H.S. Yun, V. Yurchyshyn & P.R.Goode, ApJ, 2002, 574, 1066, [published, refereed]

BBSO 1136: Active Region Monitoring and Flare Forecasting, P.T. Gallagher, Y.-J. Moon & H. Wang, 2002, Sol. Phys., 209, 171, [published , refereed]

BBSO 1158: Sudden Disappearance of a Small Sunspot Associated with the February 20, 2002 M2.4 Flare, H. Wang, H. Ji, E.J. Schmahl, J. Qiu, C. Liu & N. Deng, 2002, ApJL, 580, L177, [published, refereed]

BBSO 1168: Correlation Between Speeds of CMEs and the Intensity of Geomagnetic Storms, V. Yurchyshyn, H. Wang & V. Abramenko, 2003, Space Weather, submitted

Signature of Avalanche in Solar Flares as Measured by Photospheric Magnetic Fields, V.I. Abramenko, V.B. Yurchyshyn, H. Wang, T.J. Spirock & P.R. Goode, 2003, ApJ, [in press, refereed]

BBSO 1186: Magnetic Helicity Changes of Solar Active Regions by Photospheric Horizontal Motions, Y.-J. Moon, J. Chae & Y.D. Park, 2003, J. Korean Astron. Soc., [in press, refereed]

HONORS/AWARDS/PRIZES

Halan J. Perlis Research Award to Haimin Wang, New Jersey Institute of Technology, awarded by New Jersey Institute of Technology, 2003